The Pennsylvania State University
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College of Engineering

USING AN UNDER DESK BIKE IN THE OFFICE WORKPLACE: A PILOT STUDY

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by
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Abstract

Prolonged seated posture in a sedentary office workstation is one of the major reasons that is causing the rising trend in obesity. To promote exercise in the office, this study investigates in using a desk-compatible recumbent bike in a workstation from two aspects. One is to provide workstation design guidelines that would accommodate 95% of the U.S. population. The other is to see if reading and typing can be carried out without hindrance. Twelve participants were required to select their preferred workstation settings and perform the reading and typing tasks while pedaling at three different conditions: no cycling, 10 and 25 W. By using the anthropometric variability and the user preference from the sample, the adjustable range of the workstation settings for the general U.S. population was derived: seat height 382 - 455 mm, desk clearance 692 - 835 mm, desk depth 595 - 832 mm, and required minimum total distance 1243 - 1487 mm. Repeated measures ANOVA revealed that reading comprehension was not affected while pedaling ($p > .05$), but typing was affected at higher watts ($p < .001$). A preferred level of cycling intensity was determined (mean 16.5 W, σ: 0.6).

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Chapter 1
Introduction

Increased prevalence of overweight and obesity has definitely become one of the most significant epidemics in the U.S. In the year 2008, the prevalence of obesity was almost 34% for both adult males and females, which is approximately a 10% increase compared to the past decade (Flegal et al., 2010). Attention is required to this increasing trend since obesity is highly correlated to causing diseases such as diabetes, coronary heart diseases, cancer, and etc. (Wang et al., 2011). One of the major reasons for this inclination is due to the majority of working/studying environment altering to a sedentary computer based setting in developed and high- income countries (Ma et al., 2009).

Typically, U.S. adults employed in sedentary occupations remain deskbound for approximately 11 hours a day (Tudor-Locke et al., 2011). This prolonging seated posture in the office requires little movement, which causes not only weight gain, but also strain on the back, wrists, neck, and etc. (Gerr et al., 2004). Hill et al. (2003) stated that even walking 15 minutes a day and eating a few less bites could have significant effect in terms of preventing weight gain. However, change in lifestyle and sedentariness in occupations these days make it difficult to invest time in exercising.

Many studies have been conducted to find methods of exercising in an office work setting to overcome these issues. Levine & Miller (2007), for example, experimented the use of a vertical office workstation along with a treadmill and found that energy expenditure could increase by 100 kcal/h if the sitting computer-time was replaced by walking-and-working. Straker et al. (2009) observed the effects of two active workstation designs, a treadmill and a cycle ergometer, on three different computer tests: typing, mouse-pointing, and a combined task. Results indicated that the performance on mouse related tasks were affected more for both active workstations and the participants had lower performance on the tests when using the treadmill.

Although a variety of occupational ergonomics studies with respect to work/exercise have been conducted, studies on fitting the human into these methodologies are lacking. It is critical to incorporate anthropometric measures and user preferences when designing artifacts in order to meet the needs of the user population (HFES 300 Committee, 2004; Garneau & Parkinson, 2009). Especially when these artifacts concern physical activity (e.g., cycling) since proper fit can increase performance, efficiency, comfort, and most importantly it can prevent injuries (Laios & Giannatsis, 2010).

The purpose of this study was to (1) determine the preferred office workstation settings with respect to anthropometric measures, (2) determine whether physical exercise affects cognitive performance, and (3) what exercise level is preferred when using a desk-compatible recumbent bike in the office workstation. The results from this study can be used to provide guidelines in designing office chairs and desks that can be used with a desk-compatible recumbent bike and recommend exercise levels on the recumbent bike that allows working in an office workstation without any hindrance in the cognitive performance.

Chapter 2
Methods

2.1 Participants

Twelve college students were recruited through online advertisements at a large northeastern university in the U.S. The participants consisted of 7 males and 5 females that were healthy with an average age of 20.7 (σ = 1.92). For both genders, participants were recruited based on 5th, 50th, and 95th percentile stature according to NHANES 2007-2010 (Fryar et al., 2012). All participants had sufficient experience in using a mouse and keyboard for general computer usage. and received compensation. The study was approved by the Human Subject Research IRB at Penn State University. All participants read and signed the informed consent prior to participation in the study and received compensation.

2.2 Anthropometric Measurements

Anthropometric measures were collected based on the right side of participants using an anthropometer (Model 101, GPM, Switzerland). The measures in this study adopted the standards from the 1988 U.S. Army Anthropometry Survey (ANSUR; Gordon et al., 1989): stature (ST), weight (WT), trochanteric height (TH), sitting height (SH), knee height (KH), popliteal height (PH), buttock-knee (BK), buttock-popliteal (BP), and elbow rest height (ER) (Figure 2.1).

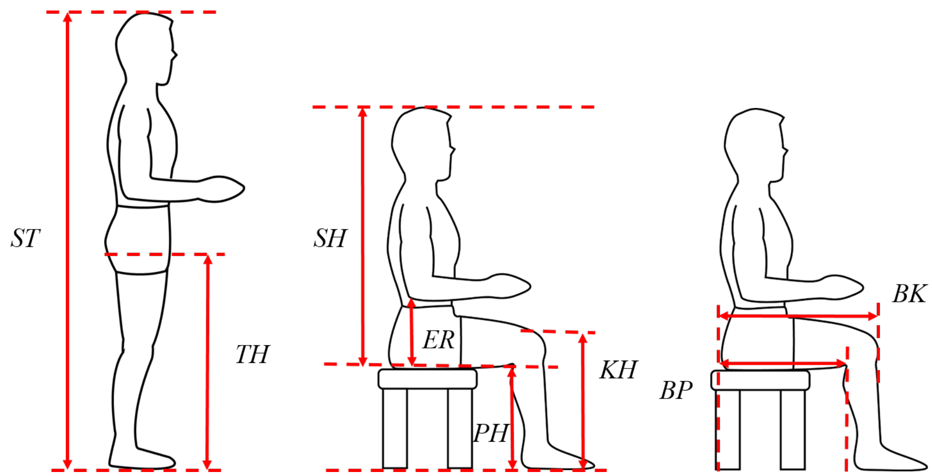

Figure 2.1. Anthropometric Measurements

Subjects were standing erect without shoes when measuring stature and trochanteric height. Other measures were taken with subjects seated on a flat horizontal surface, elbows and knees flexed 90 degrees (measured with a goniometer), and feet set parallel to thighs on an height adjustable flat horizontal surface in a relaxed and erect posture.

2.3 Experimental Setup

A simulated office workstation was set up in a controlled lab $(54.1m^3; 3.6 \times 4.7 \times 3.2m)$ with the temperature set to 23.3°C. The workstation consisted of an office chair (Aeron Chair, Herman Miller, Zeeland, MI, USA) and a customized workstation desk (two adjustable industrial workstations connected with a flat plywood surface; $2.2 \times 125 \times 70cm$). A standard PC was set up running Windows 7 with a height adjustable 24” wide LCD monitor (16:9 ratio, 1920 x 1080 resolution, and 60Hz; Figure 2.2). The seat height, desk height, and desk depth were adjustable in a continuous manner.

Figure 2.2. The Simulated Office Workstation

The desk-compatible recumbent bike used in this study was the DeskCycle (3D Innovations LLC., Greeley, CO, USA; Figure 2.3). The features on the DeskCycle are: a knob dial to change the resistance (levels 1-8), a Velcro tether strap which keeps the chair from rolling, an adjustable strap for different feet size, and a monitoring device (which shows speed, time pedaled, distance pedaled, and estimated calories burned).

Figure 2.3. The DeskCycle and its dimensions and features (3D Innovations LLC., Greeley, CO, USA)

Participants were able to adjust the seat height pneumatically, while the desk height and depth were adjusted by the facilitators according to participants' request. Figure 2.4 shows the dimensions of the workstation that were measured: seat height (sh), desk clearance (dc), desk depth (dd), and required minimum total distance (td).

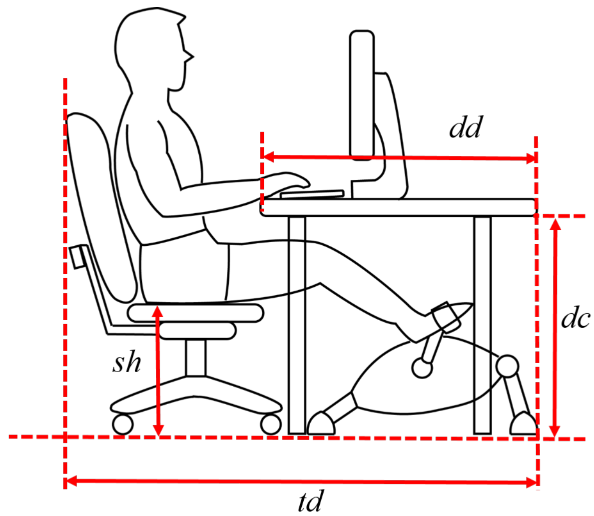

Figure 2.4. The Measured Dimensions of the Office Workstation

2.4 Reading Comprehension and Typing Tasks

Participants were required to read a short article and answer five multiple-choice questions, each with four choices. All passages had an average of 280 words (from 250 to 305) and were written at an 8th grade level, which is considered as the average U.S. adult reading level (Kirsch, 1993). The passages were from Reading for Comprehension Level H (Continental Press, 2007; Approved by New York State Textbook Law) and were computerized with permission (Figure 2.5). The reading time and the selected answers were recorded for each passage. Twenty passages were prepared and eight passages were randomly selected for each participant (1 practice and 7 actual testing).

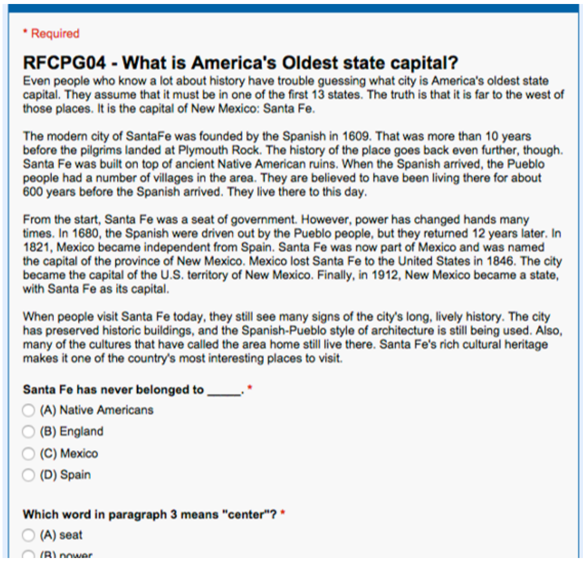

Figure 2.5. An example of the reading comprehension task

Participants were required to copy a non-technical passage as fast and as accurately as possible for two minutes using TypingMaster Pro Lite (TypingMaster Inc., Helsinki, Finland). TypingMaster Pro Lite is a typing tutor software that features a split-screen display, where the top window shows the text required to be copied and the bottom window shows an open text box for the text to be typed (Figure 2.6). The software provided results in adjusted words-per-minute (AWPM), which takes the product of gross words-per-minute and accuracy (John et al., 2009). Eight passages were prepared (1 practice and 7 actual testing) with all having a syllabic intensity of approximately 1.3 (Straker et al., 2009).

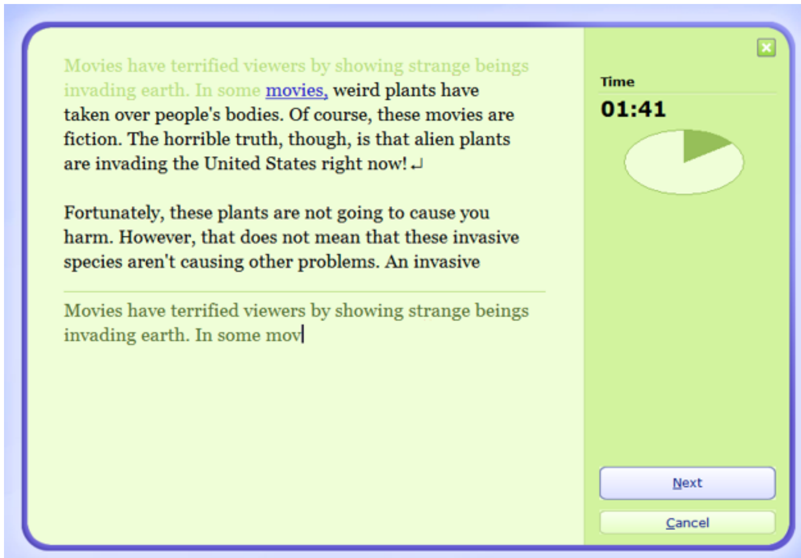

Figure 2.6. An example of the typing task

2.5 Subjective Ratings

The Borg Rating of Perceived Exertion (RPE) Scale survey was provided to the participants to estimate perceived exertion on the worker with respect to physical activity (Figure 2.7; Borg, 1982).

Rating	Verbal Description
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Figure 2.7. Borg Rating of Perceived Exertion given to estimate perceived exertion

At the end, participants were asked two questions in terms of evaluating the desk-compatible recumbent bike:

1. Do you think the DeskCycle would be feasible in terms of your desk?
2. How did you feel about completing the tasks while pedaling the DeskCycle?

2.6 Procedure

A brief overview of the study was provided and informed consent was attained. The anthropometric measures were obtained following with an introduction to the workstation and the DeskCycle. Participants were required to adjust the workstation to their preference and were taught how to perform the reading comprehension and typing tasks. This was practiced out enough to eliminate the possibility of having a learning effect. After the practice session, the workstation settings were set to random settings. Last, the participants were provided with instructions on the procedure, which concerns three cycling conditions (for two replicates in a randomized order) and one desired level. An example of one trial would be, practice - sitting - high - sitting - low - low - high - desired (Figure 2.8)

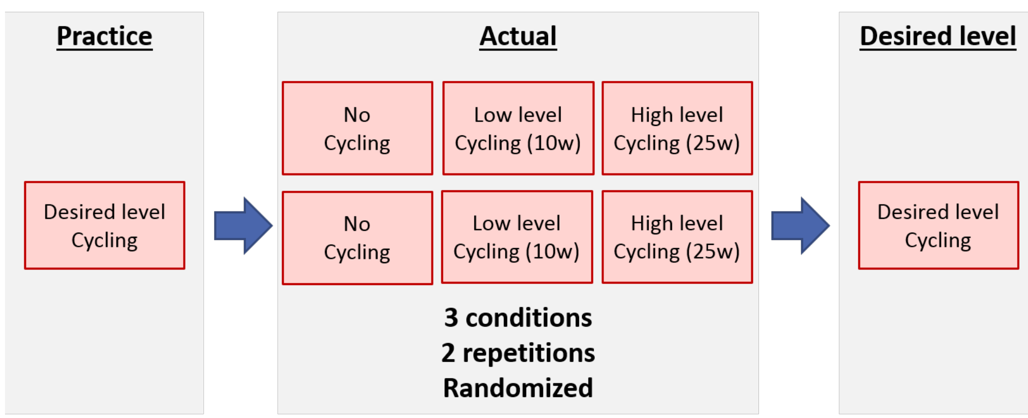

Figure 2.8. A flow diagram of the procedure

2.6.1 No Cycling (Sitting)

First, the participants were required to adjust the office workstation settings to their preference. Then the participants were required to complete a reading and typing task (in that specific order). After completing the tasks, the participants were required to complete a survey on their perceived exertion (Borg RPE). The settings on the office workstation were set back to random settings.

2.6.2 Cycling (Low/High/Desired)

First, the participants were required to adjust the office workstation settings to their preference. Next, the participants were required to start pedaling and steadily increase the power to 10/25/desired watts and reach steady state within 2 minutes. Then the participants were required to complete a reading and typing task (in that specific order) while pedaling. If the participants started to lose pace, an auditory indicator (a small beep) was provided. After completing the tasks, they were required to complete a survey on their perceived exertion (Borg RPE) following with a two-minute rest to avoid fatigue residual effect. The settings on the office workstation were set back to random settings. Figure 2.9 shows the detailed steps for each red block session shown in Figure 2.8.

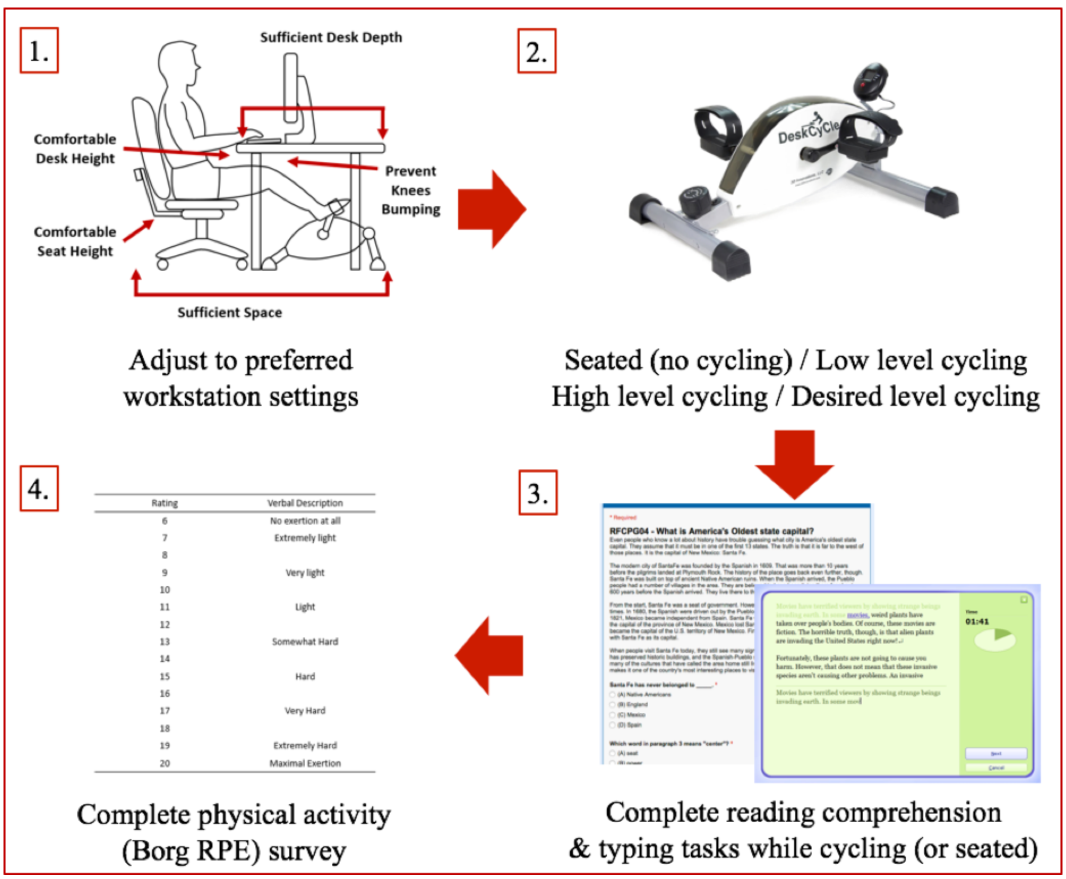

Figure 2.9. Procedure for each cycling condition

2.7 Data Analysis

The hybrid model with residual variance was used to obtain the adjustable range of the office workstation settings (e.g., seat height), which would accommodate 95% of the U.S. population (Garneau & Parkinson, 2009). First, preferred workstation settings were obtained from the sample. Second, a virtual population was created using NHANES (Fryar et al., 2012) and ANSUR (Gordon et al., 1989) data. Last, preferred workstation settings were extrapolated by using the virtual population and the preference models created from this study. All statistical analyses was performed with SPSS software version 22 (SPSS Inc., Chicago, IL, USA) and Minitab 16 (Minitab Inc., State College, PA, USA).

Chapter 3

Results

3.1 Anthropometry and Preference for Workstation Settings

Baseline sample characteristics are shown in Tables 3.1 and 3.2.

Table 3.1. Summary of Age and Anthropometric Measurements

	Age	$ST\ (mm)$	$BMI\ (kg/m^2)$	$KH\ (mm)$	$PH\ (mm)$
Mean	20.7	1702.8	24.65	530.3	424.8
σ	1.92	122.7	3.8	46.2	35.6

Table 3.2. Summary of Preferred Workstation Settings (mm)

	sh	dc	dd	td
Mean	423.3	767.7	732.9	1354.4
σ	18.1	44.1	59.3	74.4

To relate preferred office workstation settings to the sample study, regression models were created using stature (ST), knee height (KH), and popliteal height (PH) as predictors (other anthropometric measurements showed weaker correlation).

$$sh = 0.384 \times PH + 260 + N(0, 12.406) \tag{3.1}$$

$$dc = 0.339 \times ST + 191 + N(0, 15.391) \tag{3.2}$$

$$dd = 1.26 \times PH + 196 + N(0, 40.579) \tag{3.3}$$

$$td = 1.51 \times KH + 553 + N(0, 26.9) \tag{3.4}$$

The four regression models (3.1) - (3.4) have an R^2 value of 0.571, 0.889, 0.575, and 0.881, respectively (all $p < .001$). They also take preference into account by incorporating a stochastic variable (normal distribution with mean zero and standard deviation equal to the residual variance). Therefore, the variability in each workstation setting can be explained by both anthropometry and preference.

The general U.S. adult population (NHANES 2007-2010) was synthesized into the preferred office workstation setting models. Although stature was included in the NHANES data, popliteal height and knee height were not included. Therefore, the ANSUR data was used to obtain the proportionalities between (1) stature (ST) and knee height (KH) and (2) stature (ST) and popliteal height (PH) for both genders. The regression models for the male virtual population are:

$$KH_m = 0.37 \times ST_m - 90.646 + N(0, 12.982) \tag{3.5}$$

$$PH_m = 0.318 \times ST_m - 123.56 + N(0, 13.042) \tag{3.6}$$

Regression models (3.5) and (3.6) have an R^2 value of 0.784 and 0.726, respectively (both $p < .001$). The regression models for the female virtual population are:

$$KH_f = 0.355 \times ST_f - 62.577 + N(0, 13.571) \tag{3.7}$$

$$PH_f = 0.301 \times ST_f - 101.61 + N(0, 14.003) \tag{3.8}$$

Regression models (3.7) and (3.8) have an R^2 value of 0.734 and 0.652, respectively (both $p < .001$). The regression models include residual variance as people with the same stature may contain varying length in popliteal height and knee height. A virtual population (ST, KH and PH) was extrapolated by using the stature of 5635 males and 5966 females from the NHANES 2007-2010 data (weights carried out appropriately) into the above proportionality equations.

Finally, preferred workstation settings were extrapolated by using Equations (3.1) - (3.4) and the virtual population. Figure 3.1 shows an example of extrapolating sh using PH. Table 3.3 shows the recommended adjustable ranges of the office workstation settings that would accommodate 95% of the U.S. population when using a desk-compatible recumbent bike.

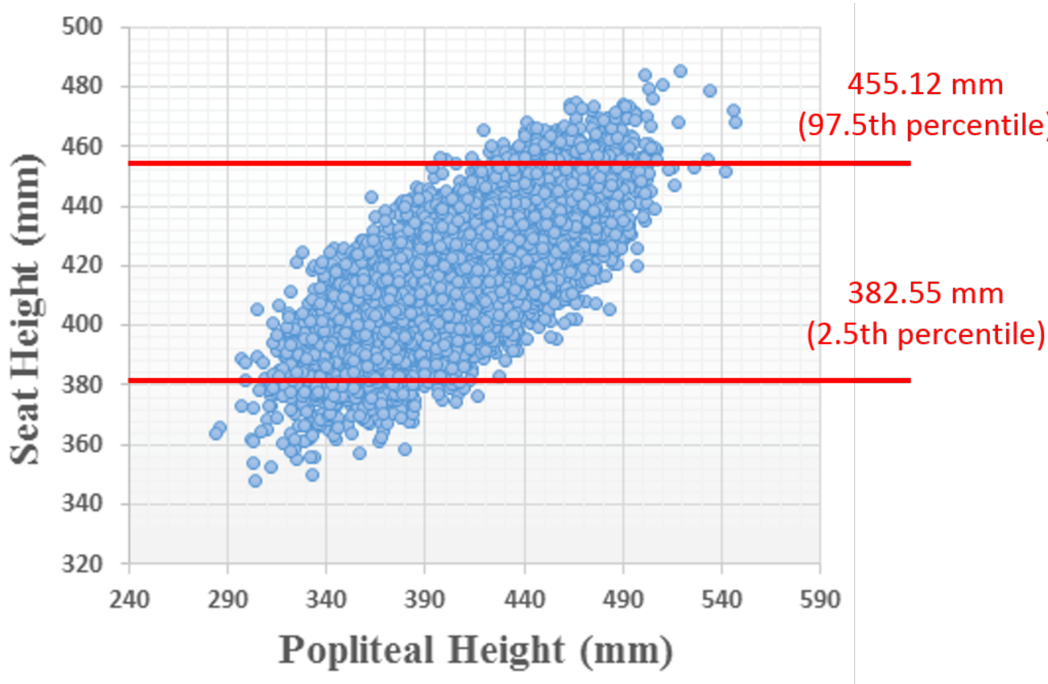

Figure 3.1. Adjustable range of seat height (sh) to accommodate 95% of the U.S. population

Table 3.3. Recommended Adjustable Ranges of Workstation Settings when using the DeskCycle (mm)

	2.5th percentile	97.5th percentile
seat height	382.55	455.12
desk clearance	691.91	835.88
desk depth	595.22	832.27
required minimum total distance	1243.39	1486.96

3.2 Effects of Cycling on Reading Comprehension and Typing

Repeated measures ANOVAs determined that cycling condition had no significant effect on reading comprehension time $(F(2,22) = 1.69, p = .208$, Figure 3.2$)$ and on reading comprehension accuracy $(F(2,22) = .762, p = .478$, Figure 3.3$)$.

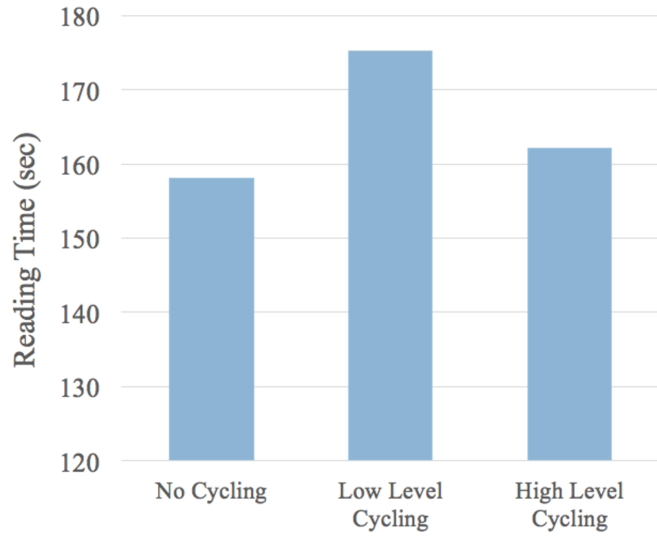

Figure 3.2. Effects of Cycling Condition on Reading Time (sec)

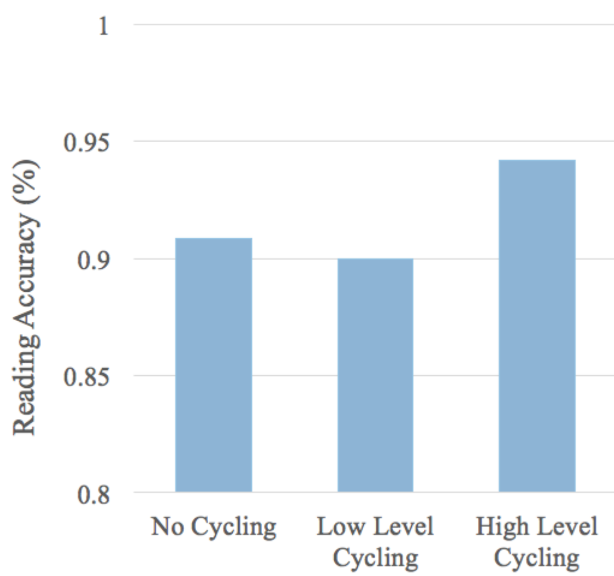

Figure 3.3. Effects of Cycling Condition on Reading Accuracy (%)

Repeated measures ANOVA determined that cycling condition had significant effect on adjusted words-per-minute (AWPM) values ($F(2,22) = 19.75, p < .001$). Bonferroni correction revealed that there was no significant difference ($p = .179$) in AWPM between no cycling and low level cycling. However, the AWPM for high level cycling was significantly different ($p < .001$) compared to the other two conditions (Figure 3.4).

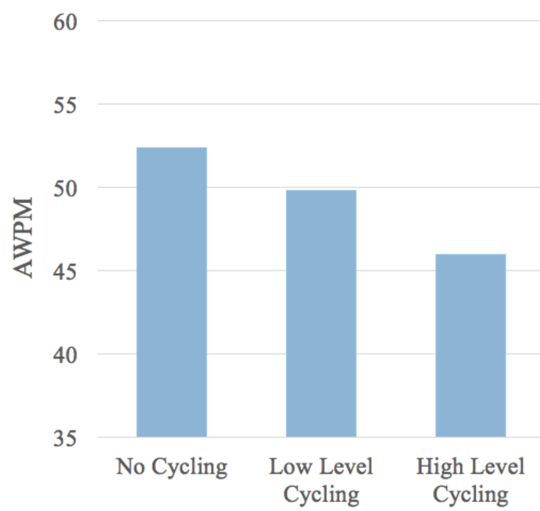

Figure 3.4. Effects of Cycling Condition on AWPM

3.3 Borg Rating of Perceived Exertion (RPE)

Repeated measures ANOVA determined that cycling condition had significant effect on Borg RPE $(F(1.244, 13.684) = 33.67, p < .001)$. Bonferroni correction revealed that all three conditions were significantly different from each other (all $p < .01$, Figure 3.5).

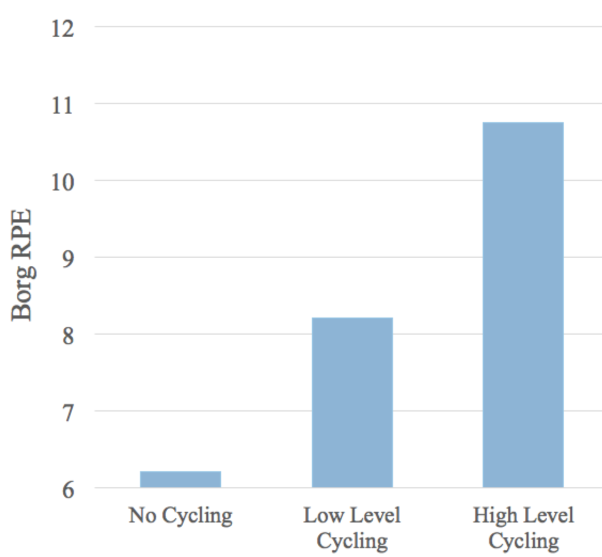

Figure 3.5. Effects of Cycling Condition on Borg RPE

3.4 Preferred Level of Cycling

After performing all the controlled exercise levels, participants were required to pedal at their desired level. The desired level had an average of 16.5 W $(\sigma : 0.6)$.

Chapter 4
Discussion

This study has investigated the ergonomic characteristics associated with using an under desk bike (i.e., the DeskCycle for this study) in an office workstation. The results of this investigation determined: (1) the adjustable ranges for the workstation settings when using a desk-compatible recumbent bike, (2) that cycling did not have significant effect on reading comprehension, (3) that higher cycling level had significant impact on typing tasks, and (4) the desired cycling level is 16.5 W (σ: 0.6), on average, when performing the reading comprehension and typing tasks.

ANSI/HFES 100-2007 suggested that the height of chairs should have a minimum adjustable range of 381 mm - 558.8 mm, which the derived seat height (sh) range from this study has satisfied. However, ANSI/HFES 100-2007 suggested that the adjustable range for the workstation height (dh) should be 558.8 mm - 718.8 mm and the depth (dd) be 440 mm at the knee level and 600 mm near the foot area. This is much lower compared to the results obtained from this study. This is mainly due to the cycling motion, which adds a range of motion beneath the work surface. Therefore, in order to accommodate 95% of the U.S. population in using the desk- compatible recumbent bike in this study, office desks will need additional adjustable range for dh and dd.

Although the study provided guidelines for the workstation adjustable ranges by employing anthropometry and preference, two major limitations were observed in this process. One was the statistical power being very low due to the small sample size and not representing the general U.S. population. Even though the participants were recruited with respect to the 5/50/95th percentile stature values for both genders, the BMI (and its variation) was much lower compared to the U.S. population ($24.65<27.5\ kg/m^2$). The other is that proportionalities were obtained by using the ANSUR data, which was collected from the military population and approximately 25 years ago. This would indicate that the data might not be optimal in representing the civilian population and that secular trends could have affected the proportionalities (Malina et al., 2004). It is recommended that more data to be collected in future work in order to better represent the general user population.

The cycling condition had different effects on the reading comprehension and typing tasks.

The reading comprehension performance was not affected by the cycling condition. However, participants have commented that clicking on the proper answer took effort due to targeting the small radio button on the screen and also requiring to pedal at the same time. This would be difficult since it requires the upper limbs to perform fine motor skills while the lower limbs perform gross motor skills (Winter, 1995). This suggests that fine motor skills, such as mouse pointing, would not be the best type of task to do while cycling on the desk-compatible recumbent bike. The typing task on the other hand was only affected when cycling at higher levels. Feedback from participants indicated that maintaining the selected speed was difficult and affected their performance on the tasks, which also corresponded to the study by Straker et al. (2009). Future work could utilize the desired cycling level in order to diminish the attention shifting from the task to the exercise in typing tasks.

Since this research is still in the early stage, further studies can be conducted to find the optimized workstation settings and suitable tasks that can be performed while exercising in the everyday office. In the long run, this could lead to providing an improved work environment for the worker and prevent obesity from growing.

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